S P E C I F I C A T I O N

TITLE OF THE INVENTION

5   COMBINED PREAMBLE DETECTION AND INFORMATION TRANSMISSION

METHOD FOR BURST-TYPE DIGITAL COMMUNICATION SYSTEMS

This application claims the benefit of priority of U.S.

Provisional Application No. 60/051,234, filed June 30, 1997.

10

BACKGROUND OF THE INVENTION

1)   Field of the Invention

This invention pertains to the field of digital

15 communication systems, and more particularly to digital

communication signal detection and synchronization.

2)   Background of the Related Art

Many modern digital communications systems utilize burst

20 type transmissions in which a relatively small number of

information bits are transmitted by sending a sequence of a small

number of waveforms, say "N" in number, termed "symbols," each of

which symbols can assume one of "Q" possible shapes. As an

example, Q=4 for the case of quadraphase shift keying (QPSK).

1

In a burst-type communication system it is important to
rapidly detect the onset of the signal at the receiver and to
perform time synchronization to it. To facilitate this, in many
burst-type communication systems a burst consists of a initial
set of symbols, termed a "preamble," which permits rapid
synchronization, and a subsequent set of symbols, termed a
"payload," which represents the actual message data. Some
systems also include special data in the middle of the burst, or
at the end, which is termed a "postamble."

Time synchronization for a burst-type communication system
includes two aspects: (1) determining the timing of the symbols,
and (2) determining the onset of the actual payload data carried
by the burst. It is important that such synchronization be
performed using the preamble data so that the payload data may be
correctly decoded. Determining the onset of payload data in a
burst transmission is typically performed through the
transmission during the preamble of a specific sequence of
symbols, termed a "unique word."

Time synchronization is to be distinguished from
determination of received signal carrier frequency and phase,
which is termed "carrier synchronization."

2

In addition to allowing time synchronization, the preamble may be used to transmit a limited amount of information that describes the subsequent payload data. For example, such information may specify the length of the payload (number of symbols), the modulation format of the payload data, or other information.

In conventional systems the above information is sent in the preamble by the normal manner of associating individual symbols with information bits. However, in situations in which the received signal level is low, such individual symbols may be obscured by noise such that this conventional approach will lead to very high error rates.

Accordingly, it would be advantageous to provide a system and method which will perform both time synchronization and information transmission via a preamble when the input signal level is low. Other and further objects and advantages will appear hereinafter.

SUMMARY OF THE INVENTION

The present invention comprises a combined synchronization
and information transfer method and system in a burst-type
5   communication system.

In one aspect of the invention, a burst-type communication
system employs differential encoding and decoding. Differential
decoding operates on the differentially encoded data to remove
10   the effects of signal carrier frequency uncertainty from the
signal and enables processing a large number of symbols by a
subsequent matched filter without the deteriorating effects of
such carrier frequency uncertainty.

15   In another aspect of the invention, a burst-type
communication system employs matched filtering, permitting
integration of a received signal over a large number of symbols,
thereby producing a strong detection output even when the
individual signal symbols are weak relative to the noise level.
20   This integration may permit detection even when, for example, the
power of the symbols equals the power of the noise.

In yet another aspect of the present invention, each burst
transmission in a burst-type communication system includes one of

a number "S" allowed synchronization sequences, S > 1. A

receiver includes one or more multiple matched filters to decide

which of the S allowed synchronization sequences was transmitted.

5   In a further aspect of the present invention, one of two

synchronization sequences may be transmitted, such that after

differential decoding, the two synchronization sequences only

differ from one another by a polarity inversion. In this case a

single matched filter may be used to detect both synchronization

10   sequences.

In yet a further aspect of the present invention, one or

more bits of preamble information is communicated in a

synchronization sequence in a burst transmission. Each burst may

15   include one of "S" allowed synchronization sequences. The

selection of a particular synchronization sequence among the "S"

allowed synchronization sequences communicates $\log_2(S)$ preamble

information bits. Each synchronization sequence may be divided

into two or more sections with one or more bits of information

20   communicated in each section.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows terminals in a burst-type communication system which may incorporate one or more aspects of the present invention.

Figure 2 is a functional block diagram of a preferred embodiment of a preamble detector in a communication receiver for burst-type transmissions.

Figure 3 is a simulated output of a unique word matched filter when receiving a unique word synchronization sequence.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments and other aspects of the invention described herein, including the system embodiments described below, may be made or used in conjunction with inventions described, in whole or in part, in co-pending U.S. Patent Application Serial No. 09/050,114 filed March 30, 1998 in the name of inventors Philip Freiden, David Decker, Michael Serrone and Norman Krasner entitled "Correlator Method and Apparatus" which is hereby incorporated by reference as if fully set forth herein.

Figure 1 shows a burst-type communication system 100 comprising a plurality of communication terminals 110. Each

communication terminal 110 comprises a transmitter 120 and a

receiver 130. As shown in Figure 1, the burst-type communication

system 100 may also have a communication hub 140 which may

simultaneously communicate with a plurality of the communication

5   terminals 110. In that case, the communication hub 140 may

comprise a plurality of communication receivers 150 and a

transmitter 160.

Some burst-type communication systems may use symbols which

10   are very simple in nature, such as binary phase shift keying

(BPSK) using a simple sinusoid or its inverse with duration "T."

Other systems may use a direct sequence spread spectrum (DSSS)

signal with a more complex symbol, for example, consisting of a

sequence of "V" subsymbols, termed "chips." In the latter case,

15   a sequence of subsymbols, or a "PN frame," produced by a PN

spreading sequence, makes up a single symbol, which in turn

typically conveys one or two bits of information.

In a preferred embodiment of a burst-type communication

20   system according to the present invention, the system may operate

in both a "non-spread" (e.g., BPSK) mode and a "spread" (i.e.,

DSSS) mode.

In the case of operation with BPSK, a transmitter transmits a bi-phase modulated signal of the form,

$$s(t) = \sum_{k=1}^{N} m_k(t - kT)\cos(w_0 t) \qquad (1)$$

5   where $m_k(t)$ is a symbol of length T, which takes the value of either +1, corresponding to a logical zero, or -1 corresponding to a logical one, and where w_0 is the carrier frequency. At a receiver, the received signal appears much like the transmitted signal of equation (1) except that it includes noise, the time of

10 arrival is unknown a priori, and the carrier frequency and phase may be somewhat in error (due to equipment oscillator differences, Doppler shift, etc.).

In a burst-type communication system, the first "P"

15 transmitted symbols in a burst transmission comprise a preamble. In a preferred embodiment of a burst-type communication system according to the present invention, P=96.

In a preferred embodiment of a burst-type communication

20 system according to the present invention, a burst communication transmitter differentially encodes data prior to transmission. A preamble synchronization sequence, termed a "base synchronization

8

sequence" or "base message" is differentially encoded to produce

an "encoded synchronization sequence" or "encoded message" m_k.

5   In a preferred embodiment, a burst-type communication system
uses one of "S" allowed base synchronization sequences as a

preamble for each burst transmission. The use of "S" base

synchronization sequences allows communication of $log_2(S)$ bits of

information, which may be used to specify one of "S" packet

lengths (or other information). In a preferred embodiment, S=4,

10   allowing two bits of information to be communicated by the

preamble synchronization sequence. By associating preamble data

bits with the selection and transmission of a synchronization

sequence, the preamble data may be received by determining which

of the allowed preamble synchronization sequences was

15   transmitted. Typically, the preamble synchronization sequence is

recovered by integrating over many received symbols. In this

way, the preamble data may be received even when the received

signal level is very low and when individual symbols are obscured

by noise.

20

A base synchronization sequence may be divided into two or

more sections. In a preferred embodiment, a base synchronization

sequence includes a first section comprising an initial detection

sequence of length "I," and a second section comprising a unique

word of length "U." In a preferred embodiment, I = 48 and U =

47.

5   In a preferred embodiment, a burst-type communication system

uses four base synchronization sequences (base messages):

Message 0:	[D0 W0]
Message 1:	[~D0 W0]
Message 2:	[D0 ~W0]
Message 3:	[~D0 ~W0]

where the notation ~W0 and ~D0 means the logical inverse of W0

and D0 respectively.

15   In a preferred embodiment, a base synchronization sequence

is of length 95 symbols, which is differentially encoded to

produce an encoded synchronization sequence with a length of 96

symbols. The first 48 symbols of the base synchronization

sequence, comprising an initial detection sequence, are used for

20   initial signal detection and symbol timing synchronization. The

latter 47 symbols, comprising a unique word, are used for message

synchronization to the onset of payload data.

In a preferred embodiment, a burst-type communication system uses a first set of four base synchronization sequences, or base messages, when operating in a non-spread, BPSK, mode and a second set of four base synchronization sequences, or base messages,

5 when operating in a PN spread, DSSS, mode.

In a preferred embodiment, in the case of operation in a DSSS mode, D0 is a sequence of 48 logical zeros, i.e.,

10
$$DO_{DSSS} = [\ 0 \ 0 \ . \ . \ . \ 0] \qquad (i.e., \ 48 \ 0's);$$

and W0 is a 47 symbol unique word:

$$W0= [1 \ 0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 0 \ 1 \ 1 \ 1 \ 1 \ 1 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 0 \ 1 \ 0$$

15
$$0 \ 1 \ 1 \ 0 \ 1 \ 0 \ 1 \ 0 \ 0 \ 1 \ 0 \ 1 \ 0 \ 1 \ 0 \ 0 \ 0]$$

The above unique word W0 has very good correlation properties, however the choice of unique word can be made programmable.

20 In a preferred embodiment, a communication receiver uses the initial portion of the preamble, comprising an initial detection sequence, to provide an symbol timing synchronization. However, when D0 is transmitted as a sequence of 48 consecutive logical zeros, then there are no transitions between symbols and hence no

information to determine symbol timing. When DSSS is employed

with a PN spreading sequence, a communication receiver may

utilize a PN matched filter, matched to the PN spreading

sequence, to convert the DSSS signal into a series of correlation

5   spikes, one per PN frame. The timing of these correlation spikes

provides symbol timing information for synchronizing the

receiver. However in the non-spread case, a different D0

sequence must be used to provide symbol timing information.

10 In a preferred embodiment, in the case of operation in a

non-spread BPSK mode, D0 is a sequence wherein every other symbol

is set to a logical zero, i.e.:

$$D0_{BPSK} = [\text{off } 0 \text{ off } 0 \ . \ . \ . \ 0 \text{ off } 0],$$

15

wherein an "off" symbol corresponds to m_k having a value of 0,

that is, the carrier is turned off for this symbol; and W0 is the

same as for the case of operation in the DSSS mode. In this

case, to determine ~D0, an "~off" symbol is the same as an "off."

20

In a preferred embodiment, a burst-type communication system

employs differential encoding of the four base synchronization

sequences to produce four encoded synchronization sequences.

In the case of operation in a PN spread (DSSS) mode, to perform the differential encoding, the first encoded symbol in the encoded synchronization sequence is defined as a logical zero, i.e., the encoded message begins with a logical zero. The

5   polarity of each succeeding message symbol is reversed if the next symbol of the base message is a one, and the polarity is unchanged if the next symbol of the base message is a zero. Differential decoding of the received encoded synchronization sequence produces the original base synchronization sequence.

10

As an example, if Message 0 is used as a base synchronization sequence, it is differentially encoded to produce an encoded synchronization sequence, or encoded message:

15
Encoded Message: [0 DO_{DSSS} W_{DSSS}]

where W_{DSSS} is the length 47 sequence:

[1 1 1 0 1 1 1 0 1 1 1 1 1 0 1 1 0 1 0 1 0 0 0 0 0 1 0 0 1 1 1 0

1 1 0 0 1 1 1 0 0 1 1 0 0 0 0]

20

If this message is differentially decoded, it produces the base Message 0, i.e. [DO_{DSSS} WO_{DSSS}]. The other three messages are encoded similarly. Conveniently, an encoded message may be

differentially decoded by a differential detector which

exclusive-or's adjacent bits in the encoded message.

It should be noted that even though W and ~W are logic

5   inverses of one another, after differentially encoding each of

these to create transmitted sequences, they are not either

logical or arithmetic inverses of one another.

In the case of operation in a non-spread (BPSK) mode, the

10   first encoded symbol in the encoded synchronization sequence is

defined as a logical zero, i.e., the encoded message begins with

a logical zero. Unlike the case with DSSS, when operating in a

non-spread BPSK mode, the data is encoded by using symbols spaced

apart by two to accommodate the "off" symbols in the DO_{BPSK}

15   sequence. The encoded message may be formed by splitting the

base synchronization sequence into two streams of even and odd

symbols, differentially encoding each stream, and then

interlacing the result.

20   As an example, if Message 0 is used as a base

synchronization sequence, it is differentially encoded to produce

an encoded synchronization sequence, or encoded message:

14

Encoded Message: [0 DO_{BPSK} W_{BPSK}]

where W_{BPSK} is the length 47 sequence:

[1 0 1 1 0 1 0 0 1 0 1 0 1 1 0 1 1 0 0 1 1 1 1 1 1 0 0 0 1 0 1 1

5   0 1 1 1 0 1 0 0 0 1 0 0 0 0 0]

To differentially decode this message, the convention is used
that an "off" is treated as a logical zero and that differential
encoding of two "offs" always produces another "off."

10

When this message is differentially decoded with respect to
every other symbol, as described above, it produces the base
Message 0, i.e. [DO_{BPSK} WO_{BPSK}]. The other three messages are
encoded similarly. Conveniently, a differentially encoded
message may be differentially decoded by a differential detector
15   which exclusive-or's together every other bit in the encoded
message.

The encoded message is mapped to transmitted data by mapping .
20   a logical 0 to +A, a logical 1 to -A, and an "off" to a 0, where
A is a peak signal amplitude. In the case where DSSS is
employed, before transmission each of the symbols is multiplied
by one PN frame, or sequence of subsymbols, to spread the signal.

Figure 2 shows a preferred embodiment of a communication

receiver 200 for detecting the signal described by equation (1)

in the presence of strong noise, as well as providing symbol and

message timing synchronization, and preamble data extraction.

5

The transmitted signal of equation (1) is downconverted to

near zero frequency using an in-phase/quadrature demodulator to

produce I and Q signals as shown in Figure 2. At this point the

signal may be represented in quadrature format as:

10

$$s_r(t) = A \sum_{k=1}^{N} m_k(t - kT - \tau) \exp(j w_1 t + j\theta) \qquad (2)$$

where t represents the unknown arrival time, w_1 represents the

near baseband frequency, and q represents unknown carrier phase.

15   The downconverted signal is provided to a Nyquist matched

filter 205, matched to the transmitted symbol. The Nyquist

matched filter 205 enhances signal energy and reduces out-of-band

noise energy. In the case of a non-spread BPSK transmission, the

data into the Nyquist matched filter is sampled at four times per

20   symbol, while the data out of the Nyquist matched filter is

sampled at twice the symbol rate. In the case of a PN spread

DSSS transmission, the data into the Nyquist matched filter is

sampled at four times per subsymbol, or 4V times per symbol, while the data out of the Nyquist matched filter is sampled at twice the subsymbol rate, or 2V samples per symbol, where "V" is the length of the PN spreading sequence.

5

When the burst-type communication system employs DSSS, the Nyquist matched filter output signal is provided to a separate subsequent PN matched filter 210 of length "V." The PN matched filter 210 is tapped at every other sample and produces a PN

10 correlation spike when the input signal matches the predetermined PN subsymbol sequence of length V stored in the matched filter. The time at which the PN correlation spike occurs may be used to provide subsymbol timing information to the receiver. As the data is processed at a rate of two samples per subsymbol (2V

15 samples per symbol), the PN correlation peak may provide timing information to an accuracy of ± 1/4 of a subsymbol period.

When the system employs a non-spread BPSK signal, the PN matched filter is bypassed.

20

The output of the PN matched filter (for DSSS), or the Nyquist matched filter (for non-spread BPSK), is provided to a delay block 215. The delay block delays the filtered data by "X" symbol periods before providing it to a controlled gate 220. In

a preferred embodiment, "X" is 64 symbols, or 64V subsymbols.

The controlled gate provides the data to the rest of the receiver

for further processing. The controlled gate 220 also provides a

start signal and a data clock to a unique word detector 225 as

5   will be described in more detail below.

The output of the PN matched filter (for DSSS), or the

Nyquist matched filter (for non-spread BPSK), is also provided to

a delay-multiplier block 230 comprising a delay 232 and a

10   multiplier 234.   In the case of a non-spread BPSK transmission,

the delay 232 is two symbols in length, corresponding to four

data samples.   In the case of a spread DSSS transmission, the

delay 232 is equal to "2V" subsymbols, corresponding to two data

samples per subsymbol for the PN sequence of length V.

15

The delay-multiplier block 230: (1) performs a differential

decoding operation on the symbols m_k, and (2) removes the effects

of the carrier.   In particular the delay-multiply operation

produces the signal:

20

$$s_r(t) = A^2 \exp(jw_1 T) \sum_{k=1}^{N} m_k(t - kT - \tau) m_k(t - kT - T - \tau) \quad (3)$$

If M(t)=m(t)*m(t-T), then (3) becomes:

18

$$s_r(t) = A^2 \exp(jw_1T) \sum_{k=1}^{N} M(t - kT - \tau) \qquad (4)$$

Because the signal (2) above is complex, the multiplication is also actually complex, with one of the terms conjugated. This leads to equations (3) and (4). Note that differential decoding has removed the carrier phase uncertainty from the received signal.

The data M corresponds to the original data that was differentially encoded at the transmitter to construct the encoded message that was transmitted.

In a preferred embodiment, the first symbols of a burst transmission correspond to a base message (or base synchronization sequence). In the case of DSSS transmission employing the base messages M0, M1, M2 and M3, the initial portion of the message corresponds to $D0_{DSSS}$ or ~$D0_{DSSS}$. In that case, the first 48 symbols are either logical zeros or logical ones, and the received and differentially decoded signal can be integrated over these 48 symbols to detect the start of a received burst transmission.

In the case of non-spread BPSK transmission employing the base messages M0, M1, M2 and M3, the initial portion of the message corresponds to $D0_{BPSK}$ or $\sim D0_{BPSK}$. In that case, every other symbol among the first 48 symbols are either logical zeros or

5 logical ones, and the received and differentially decoded signal can be integrated over these 24 symbols to detect the start of a received burst transmission.

In the preferred embodiment of Figure 2, the output of the

10 delay-multiplier 230 is provided to a delay line integrator 240, comprising an adder 242, a delay 244, a feedback summer 245, a multiplier 246, and a feedback ratio constant 248. In the case of a non-spread BPSK transmission, the delay 244 is two symbols in length, corresponding to four data samples. In the case of a

15 spread DSSS transmission, the delay 244 is equal to "2V" subsymbols, corresponding to two data samples per subsymbol for the PN sequence of length V. The delay line integrator 240 is a leaky integrator with a time constant of "K" symbols and a feedback ratio constant 248 equal to (K-1)/K. The feedback

20 constant 248 may be programmable. In the case of DSSS transmission, K may be 32 symbols, whereas in the non-spread BPSK case, K may be 16 symbols.

The delay line integrator 240 integrates the received signal to produce an initial detection signal. When the received signal corresponds to the initial detection sequence D0 or ~D0, then the delay line integrator 230 produces an initial signal detection

5   peak, which is either positive or negative in accordance with whether D0 or ~D0 is received.

The output of the delay line integrator 240 is provided to a threshold detector 250. The threshold detector 250 is also

10   supplied with an initial detection threshold 255, which may be a programmable value from a microprocessor. The threshold detector 250 determines the timing of an initial signal detection peak to provide symbol (or subsymbol) timing information for the receiver 200. In response to an initial signal detection peak, the

15   threshold detector produces an initial detection strobe signal 257 when both the absolute value of the initial signal detection peak exceeds the threshold 255, and is a local peak signal.

The threshold detector 250 also performs an interpolation to

20   determine whether the initial detection strobe signal 257 corresponds to a "true peak." The threshold detector 250 provides a two-bit peak timing output signal 259 indicating whether the initial detection strobe signal 257 was "early," "late," or "punctual" with respect to the true peak.

When the threshold detector 250 qualifies the delay line integrator output as an initial detection peak, the threshold detector provides the initial detection strobe signal 257 to a first input of an initial detection gate 260. The second input

5   of the initial detection gate 260 is connected to the output of a flip-flop 270. The flip-flop 270 is reset to enable an Initial Detection Output Signal 265 from the gate 260 during time periods when the receiver is seeking a burst-type transmission, and is set to disable the Initial Detection Output Signal 265 during

10   time periods when the receiver is not seeking a burst-type transmission, for example because it is busy processing another signal. The Initial Detection Output Signal 265 indicates detection of an initial detection sequence for a burst transmission and provides symbol timing for the burst. The

15   Initial Detection Output Signal 265 may be provided to a microprocessor or to an arbitration circuit in a receiver which may control the flip-flop 270.

The threshold detector 250 is a double detector which

20   detects both positive and negative peaks, as the peak signal polarity is either positive or negative, depending upon whether D0 or ~D0 is transmitted. This polarity of the initial detection strobe provides a first preamble information bit, Bit0,

indicating whether D0 or ~D0 was received. The first preamble

information bit, Bit0, is provided to the unique detector 225.

After the initial detection sequence of length I, the

symbols that follow represent a unique word of length U. In a

preferred embodiment, I = 48 symbols and U = 47 symbols.

Detection of the unique word is performed by the unique word

detector 225. Because the initial detection strobe is produced

by integrating the received signal over many symbols, the first

preamble information bit may be received even when individual

received symbols are weak relative to the noise level.

The controlled gate 220 receives an Enable Unique Word

Detect signal 221 from an arbitration circuit or a microprocessor

in the communication receiver, synchronized to the symbol timing

determined by the threshold detector 250 and provided in the

Initial Detection Output Signal 265. The controlled gate uses an

internal counter to produce a unique word data clock signal 223,

providing one clock cycle per data symbol in the received base

synchronization sequence. The counter is synchronized to the

received symbols by the Enable Unique Word detect signal 221

which in turn is synchronized to the time of occurrence of the

peak in the initial detection strobe signal 257. For the DSSS

case, the counter produces one clock cycle per PN frame.

The delay-multiplier 230 provides the differentially decoded base synchronization sequence data to the unique word detector 225 for detection of the unique word. The base synchronization sequence data is clocked into the unique word detector 225 by the

5   unique word data clock signal 223 provided by the controlled gate 220. The unique word detector 225 may adjust the timing of the unique word data clock signal 223 using the two-bit peak timing output signal 259.

10   In a preferred embodiment, the unique word detector 225 has an impulse response which is a symbol-reversed version of W0, as described previously. The unique word detector 225 compares the received data to a pattern matching the original unique word W0.

15   The unique word detector 225 includes a unique word matched filter which conveniently may be implemented as a tapped delay line. In that case, the output of the unique word matched filter is low in amplitude until the input data corresponding to the unique word is time aligned with the matched filter taps, at

20   which point a strong positive or negative going peak occurs, depending upon whether W0 or ~W0 is received. The time of occurrence of this peak determines the time-of-arrival of the message, i.e., it provides payload time synchronization information.

The polarity of the peak in the unique word detector 225 provides a second preamble information bit, Bit1, indicating whether W0 or ~W0 was received. Thus two total bits of information are communicated in the preamble synchronization

5   sequence. The unique word detector 225 provides the first and second preamble information bits as an output 290. These bits may be used to provide four possible payload lengths, or other formatting details regarding the following payload data. Figure 3 shows a simulated output of a matched filter matched to the

10 aforementioned base unique word W0. If ~W0 were utilized instead, then the peak in Figure 3 would be negative going.

In a preferred embodiment, the controlled gate 220 provides a start signal 227 which opens a detection time window in the

15 unique word detector 225 to detect the reception of a valid unique word beginning "Y" symbols after the initial signal detection peak. The detection time window is "Z" symbol periods long, with the unique word detector including a counter to count the "Z" symbol periods. The unique word detector 225 provides a

20 unique word detection output signal 280 containing a valid unique word detection peak only during the interval of the detection time window. In a preferred embodiment, Y may be 32 symbols and Z may be 64 symbols.

Significantly, the actually transmitted differentially encoded data $m_A(t)$, corresponding to the unique word sequence W0, and the transmitted differentially encoded data $m_B(t)$, corresponding to the unique word sequence ~W0, are not sign-inverted versions of one another. Only after differential decoding are the base sequences W0 or ~W0 produced. Similarly the initial detection sequences, D0 and ~D0, do not produce transmitted sequences which are logical or arithmetic inverses of one another.

In the preferred embodiment, each section of the preamble synchronization sequence contains one of two possible base sequences of waveforms. Processing each section requires, in general, two matched filters. However, in a preferred embodiment, in each section the two base sequences differ from one another by a polarity inversion, so that only one matched filter is required in each section.

In the more general case, a burst-type communication terminal may select among more than two allowed base preamble sequences of waveforms. This allows communication of additional bits of information. In general, one of S/2 allowed base sequences of waveforms may be transmitted as an initial detection sequence in the preamble (e.g. the first 48 symbols),

26

communicating $\log_2(S/2)$ first preamble information bits.

Similarly, one of S/2 sequences of waveforms may be transmitted

as a unique word in the preamble (e.g. the last 47 symbols),

communicating $\log_2(S/2)$ second preamble information bits.

5

For example, one of four allowed sequences of waveforms may

be transmitted during an initial detection portion of the

preamble (e.g. the first 48 symbols). In general, this requires

the use of up to four matched filters in the receiver, although

10   this may be reduced to two matched filters if the four allowed

sequences are selected as two pairs, such that the base sequences

in each pair differ from each other by a polarity inversion.

This allows communication of two bits of information in the

initial detection sequence.

15

More generally, the preamble may be divided into R sections.

transmitting one of say L base sequences of symbols in each

section. In that case, the total number of bits of information

communicated in the preamble is $\log_2(L*R)$. For simplicity one

20   might choose the same set of base sequences for each section,

thus limiting the number of matched filters to at most L, and

perhaps L/2 if the base sequences are chosen as pairs of

sequences which are inverses of each another.

The transmitted symbols do not have to be simply bi-phase

shifted data, as in equation (1). More complex data, such as

quadra-phase shifted data may be utilized. In this case,

however, the unique word detector of Figure 2 may be more complex

5   since it must detect the more complex waveforms created by

differentially decoding these more complex symbols.

        While preferred embodiments are disclosed herein, many

variations are possible which remain within the concept and scope

10   of the invention. Such variations would become clear to one of

ordinary skill in the art after inspection of the specification,

drawings and claims herein. The invention therefore is not to be

restricted except within the spirit and scope of the appended

claims.

15